UNITED STATES MARINE CORPS

LESSON PLAN

PRECIPITATION

INTRODUCTION:

1. Gain Attention. Precipitation is the subject for this period of instruction, you will learn exactly what it takes for those rain drops to fall from the sky and if it is not rain what type of precipitation it is.

2. Overview. During this period of instruction the student(s) shall be introduced to the conditions necessary to form the various types of precipitation and how they are measured.

3. Introduce Learning Objectives.

a. Terminal Learning Objective. Without the aid of references, but in accordance with the instruction, the student(s) shall define and discuss the processes that produce each type of precipitation.

b. Enabling Learning Objective(s). With the aid of references, but in accordance with the instruction, the student(s) shall:

(1) Define and discuss the warm rain process and the cold rain process.

(2) State the different types of precipitation that are produced by the warm rain process.

(3) State the different types of precipitation that are produced by the cold rain process.

(4) Identify the different procedures that are used to measure liquid or solid precipitation.

4. Method/Media. This period of instruction will be taught using the lecture method with the aid of a Macromedia Flash presentation "QMMPH1-Introduction to the Dynamics of the Atmosphere".

5. Evaluation. The student(s) shall not be evaluated at the conclusion of this period of instruction.

TRANSITION. We have already learned the processes that clouds are formed by. When cloud particles become too heavy to be supported by the cloud, they fall to the Earth in the form of precipitation. The next topic introduces the processes that form the various types of precipitation.

BODY:

1. Processes that Form Precipitation. There are two (2) processes that form precipitation, the warm rain process and the cold rain process. For the purposes of this period of instruction a “warm layer” is denoted as a layer that has temperatures above freezing temperatures and a “cold layer” is denoted as a layer with below freezing temperatures.

a. The Warm Rain Process. The warm rain process occurs when clouds and precipitation form in the liquid state (above 0°C). The cloud droplets grow large enough to fall to the ground by the process of collision and coalescence. This type of process normally occurs within stratiform type clouds, but also may occur in cumuliform clouds in the tropics. In warm rain process, collisions occur between cloud droplets of varying size, with their different fall speeds, sticking together or coalescing, forming larger drops. The different types of precipitation that form as a result of this process are warm rain, drizzle and freezing drizzle. Occasionally, super cooled water droplets may also be occurring in the warm rain process.

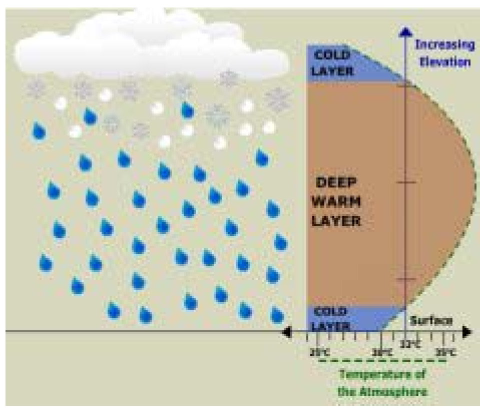

Figure 1 – Illustration of the warm rain process. The warm layer must be thick enough and warm enough to completely melt the precipitation. The surface cold layer, if any, must be shallow enough not to (re) freeze any precipitation.

b. The Cold Rain Process. The cold rain process occurs when clouds and precipitation form at or below freezing temperatures (0°C or below). The different types of precipitation that form as a result of this process are cold rain, snow, ice pellets, freezing rain and hail. This occurs in colder clouds when both ice crystals and water droplets are present. In this situation it is "easier" for water vapor to deposit directly onto the ice crystals so the ice crystals grow at the expense of the water droplets. The crystals eventually become heavy enough to fall.

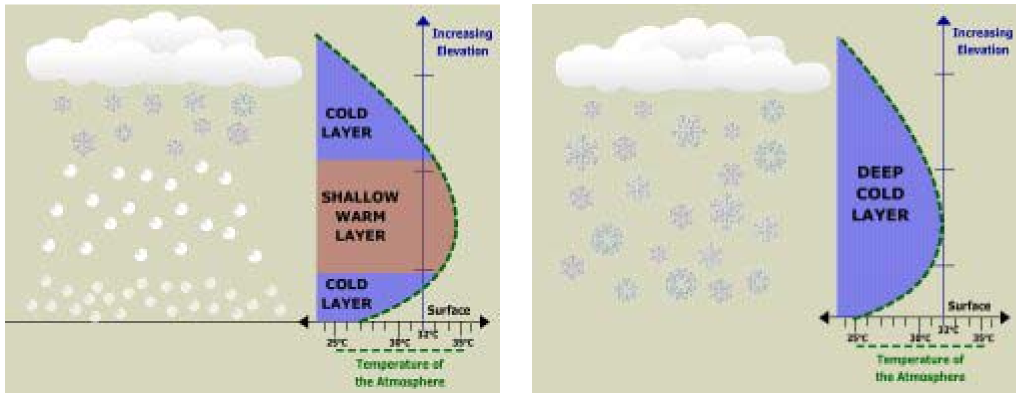

Figure 2 – Illustration of the cold rain process. The cold layer must be thick enough and cold enough to maintain frozen precipitation. The warm layer, if any, must be shallow enough not to completely melt any precipitation.

<u>TRANSITION</u>. The next section focuses on the different types of precipitation that are created by the warm rain process, then the cold rain process.

2. <u>Types of Precipitation</u>.

a. The Warm Rain Process. As previously stated, there are three (3) different types of precipitation that form due to the warm rain process; Warm rain, drizzle, and freezing drizzle.

(1) Liquid Precipitation.

(a) Warm rain. Cloud droplets grow large enough to fall to the ground by the process of collision and coalescence. Warm rain occurs primarily in stratiform type cloudiness, but may occasionally occur in cumuliform clouds within the tropics.

(b) Drizzle. Drizzle forms by coalescence in stratiform clouds with depths possibly less than 1000 feet and with only weak vertical motion, otherwise the small (0.2 – 0.5 mm) drops would be unable to fall. It also requires only a short distance or a high relative humidity between the cloud base and the surface, otherwise the drops will evaporate before reaching the surface.

(2) Freezing Precipitation. Freezing drizzle is the only type of freezing precipitation that is formed by the warm rain process. However, freezing drizzle may be formed in one of two different ways.

(a) Freezing drizzle may begin its formation while the stratus clouds is in a warm layer, a layer with temperatures above freezing). The liquid drizzle drops form then fall through a cold layer (below freezing) and super cool. Once the drizzle droplets reach the frozen surface – they will freeze on impact.

(b) Freezing drizzle may also form while the entire cloud is in a cold layer. The drizzle drops will form as super cooled water droplets (they will exist in a liquid state at temperatures below freezing). The droplets eventually fall as liquid and will freeze on contact with the Earth's surface when surface temperatures are below freezing.

b. The Cold Rain Process. As previously stated, there are five (5) different types of precipitation that form due to the warm rain process; cold rain, snow, ice pellets, freezing rain, and hail.

(1) Liquid Precipitation. The only type of liquid precipitation that forms from the cold rain process is "Cold Rain". Cold rain occurs in stratiform clouds. Rain is formed when ice crystals fall into a warm layer that is thick enough for complete melting to occur.

(2) Freezing Precipitation. The only freezing type of precipitation that is formed by the cold rain process is "Freezing Rain". Freezing rain actually begins as snow in a layer that has temperatures below freezing. The snow then falls into a warm layer, which is above freezing, and completely melts. Continuing on its descent, the now liquid precipitation will fall through another cold layer and become super cooled (similar to freezing drizzle). The droplets will remain as super cooled liquid droplets until they reach the Earth's frozen surface.

(3) Frozen Precipitation.

(a) Snow. Ice crystals grow large enough to fall through deposition and/or collision and coalescence. A warm layer may exist above the ground and below the cold layer, but it will not t=be thick enough to melt the ice crystals. Snow may form in either stratiform or cumuliform precipitation.

(b) Ice Pellets. Ice pellets (also referred to as *sleet*) begin as snow in a cold layer aloft. The ice crystals fall into a warm layer and partially melt. The droplets will then fall into another cold layer above the surface and refreeze before hitting the surface. Ice pellets may form in either stratiform or cumuliform precipitation.

(c) Hail. Hail forms as ice crystals in the upper portion of a cumulonimbus cloud. The ice crystals grow by collision and coalescence, "The Bergeron Process", as they are consistently tossed throughout the cloud by updrafts and downdrafts. Hail will eventually fall to the Earth's surface once there weight can no longer be supported by the updraft. Depending on the height of the freezing level, wet-bulb zero temperature and the base height of the cloud, hail may completely melt before it reaches the surface.

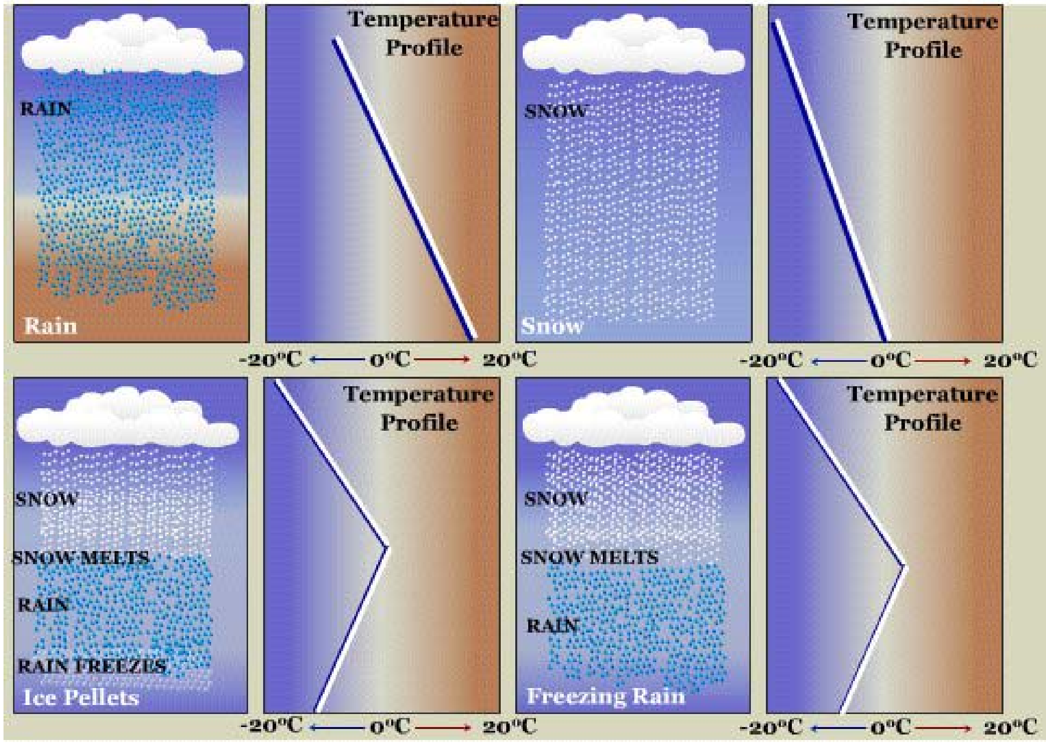

Figure 3 – Illustration depicting the different atmospheric profiles that are associated with rain, snow, ice pellets, and freezing rain.

Table 1 – Various types of precipitation.

Various Types of Precipitation			
Type	**Approximate Size**	**State of Water**	**Description**
Mist	.005 - .05mm	Liquid	Droplets large enough to be felt on the face when air is moving 1 m/sec. Associated with Stratus (fog).
Drizzle	< .5mm	Liquid	Small uniform drops that fall from stratus clouds, generally for several hours.
Rain	.5 – 5mm	Liquid	Generally produced by nimbostratus of cumulonimbus clouds. When heavy, size can vary from one place to another.
Sleet	.5 – 5mm	Solid	Small, spherical to lumpy ice particles that form when raindrops freeze whiles falling through a layer of subfreezing air. Damage is usually minor because ice particles are small. Makes travel hazardous.
Glaze	Layered 1mm – 2cm thick	Solid	Produced when supercooled raindrops freeze on contact with solid objects. Glaze can for a thick coating of ice having sufficient weight to serious damage trees and power lines.
Rime	Variable Sizes	Solid	Deposits usually consisting of ice feathers that point into the wind. They form as supercooled cloud or fog droplets encounter objects and freeze on contact.
Snow	1mm – 2cm	Solid	Easily forms in many shapes, including six-sided crystals, pates and needles. Produced in supercooled clouds where water vapor is deposited as ice crystals that remain frozen during descent.
Hail	5mm – 10cm and greater	Solid	Precipitation in the form of hard rounded pellets or irregular lumps of ice. Produced in large convective cumulonimbus clouds, where frozen ice particles and supercooled water coexists.
Graupel	2 – 5mm	Solid	Forms as rime collects on snow crystals to produce irregular masses of “soft” ice. Because they are softer than hails tones, they normally flatten on impact.

TRANSITION. We just discussed the different processes that form certain types of precipitation. The next topic discusses how to correctly measure liquid, freezing and frozen precipitation.

3. Precipitation Measurements. Amounts of precipitation are expressed in terms of vertical depth. Precipitation measurements are computed in inches, tenths of inches, or hundredths of an inch depending on the precipitation being measured. The below information describes the different procedures used in measuring the amount of precipitation.

Liquid Precipitation	0.01 inches
Liquid Equivalent of Solid Precipitation	0.01 inches
Solid Precipitation	0.1 inches
Snow depth	1 inch

a. Measurement Using a Stick.

(1) Liquid Precipitation. Insert a dry measuring stick into the measuring tube. Permit the stick to rest on the bottom for 2 or 3 seconds. Withdraw the stick and read the depth of precipitation at the upper limit if the wet portion. After measuring the liquid in the measuring tube empty it and pour the liquid (if any) from the overflow container into the measuring tube and measure it. Add the two amounts to get the total precipitation. When the measurements are completed, empty the tube and reassemble the gauge.

(2) Solid Precipitation. When solid or freezing precipitation is anticipated, remove the funnel and measuring tube from the rain gauge. To measure the precipitation, melt the contents of the overflow container, pour the liquid into a measuring tube and measure it as liquid precipitation. If, because of strong winds, the amount of precipitation is considered to be unrepresentative, disregard the catch and obtain a measurement by a vertical core sampling, as an aid in obtaining the measurement of new snowfall, snowboards may be placed on top if the snow after each measurement. Each new snowfall measurement can then be taken from the top of the snow to the snowboard.

b. Core sampling and depth measurements. Select an area that is smooth, level, preferably grass covered, and as free from drifting snow as possible. Paved areas and low spots where water tends to collect should be avoided. The size and utilization of the area should permit samples and measurements to be taken in undisturbed snow, approximately two feet apart. The deeper the snow and the greater the drifting, the greater the distance between samples will have to be in order to prevent intersection of the holes, non-representative melting, erosion, or piling up of the snow in holes. Measurements should start along the edge of the area where unnecessary tracking of the snow is avoidable.

c. Water equivalent of core samples. Irregularities caused by uneven terrain, drifting, footsteps, prior sampling, etc., usually introduce some unavoidable errors in this type of water-equivalent measurement. Some of these errors can be materially reduced by the following procedures.

(1) Measure the snow depth, to tenths of an inch, at a spot where the core sample has been taken.

(2) Measure the snow depth at the most representative location available, to tenths of an inch, as accurately as practical.

(3) Using the snow depth found in subparagraph (a) above and its water equivalent, determine the density of the snow pack by dividing the water equivalent by the depth.

(4) Multiply the snow depth in subparagraph (b) above any density of the core sample in subpara.(c) to obtain the adjusted water equivalent of the snow pack.

d. Estimating the water equivalent of snow. When the water equivalent of snow cannot be accurately measured by melting, weighing, or core sampling; estimate the water equivalent to the nearest 0.01 inch.

e. Depth measurements in solid forms. For the purposes of depth measurements, the term snow also includes snow pellets, hail, any combination of these, and sheet ice formed directly or indirectly from precipitation. Therefore, if snow falls, melts, and refreezes, the depth of ice formed will be included in the depth measurements of snow. Depth is determined to the nearest 0.1 inch.

f. Measurement of total depth. Measurement of total depth will be made in accordance with the following instructions.

g. Snow. Thrust the measuring stick vertically into the snow so that the end rests on a snowboard. Repeat several times and take the average readings. If the ground is covered with ice cut through the ice and measure the thickness. Add the thickness of the ice to the depth of the snow above the ice for the total depth measurement.

h. Drifted Snow. When the snow has drifted, a reasonably accurate depth measurement may be made by taking the average of several measurements over representative areas. These should include the greatest and least depths. For example, if spots with no snow are visible, one of the values should be zero.

OPPORTUNITY FOR QUESTIONS:

1. Questions from the Class. At this time, are there any questions pertaining to the subject material that has just been presented.

2. Questions to the Class. There are no questions for the student(s) at this time.

SUMMARY:

During this period of instruction, the student(s) were introduced to the two (2) processes that aid in the formation of precipitation; the warm rain process and the cold rain process. An explanation was provided for each type of precipitation that was presented. The student(s) were also instructed on how to properly measure precipitation as it exists in different states (i.e. liquid, freezing, and solid).

REFERENCE:

Clouds, Fog and Precipitation. Australian Ultalight Federation. Last accessed 05 Oct. 04. http://www.auf.asn.au/meteorology/section3.html.

Meteorology and Oceanographer Analyst/Forecaster (MOAF) Physics II, Chapter 6. N61RCB1-ST-104. Rev. October 2002.

Vigorous deep cloud with warm and cold rain processes. Meteorology Training and Education. Last updated 27 Sept. 04. Last accessed 05 Oct. 04.